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Coal-Resource Contracting Terms for Productive Postmining Forests

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Introduction

Many coal resource owners also own the overlying land surface; such owners negotiate contracts with mining firms as a way to generate revenue. Here, we suggest contracting terms that can be offered when the resource owner desires a productive forest on the land surface that can serve as an economic asset after mining. These terms may be offered by resource owners or by mining firms seeking coal-leasing contracts.

Background

Surface coal mining in the eastern United States has often degraded the land's capability to support productive forests (ARRI Forest Reclamation Advisory No. 1). This occurred despite the fact that reclamation practices to restore forest productivity can be applied easily and cost-effectively. Failure by coal miners to use such practices when the surface owner desires a postmining forest can be considered as an inefficient business practice. Routine business operations in competitive markets generally eliminate inefficiencies. The coal-mining business is competitive, so why does inadequate reclamation occur?

In past years, the lack of technical knowledge hindered efficient mine reforestation, but recent scientific advances have improved the understanding of what it takes to reforest a mine site effectively (Burger and Zipper 2009; Forest Reclamation Advisory No. 2). In fact, the postmining productivity of land reclaimed to forest can equal or exceed the productivity prior to mining. When mine operators are knowledgeable in both coal mining and reclamation/reforestation processes, efficient and effective mine reforestation can occur at little or no extra cost.

Also in past years, regulatory practices hindered mine reforestation. Agency inspectors often encouraged miners to grade excessively, compacting the soil surface, and to plant fast-growing ground covers – practices that hindered planted trees (Forest Reclamation Advisory No. 1). This situation is also changing and state and federal agencies now encourage reclamation practices, known as the Forestry Reclamation Approach (FRA), that are more favorable to reforestation (for example, see Virginia DMME 2008; Forest Reclamation Advisory No. 2; Burger, Mitchem, and Scott 2002).

Now that the necessary knowledge is widely available and regulatory practices are no longer an obstacle, resource owners and coal miners are free to negotiate contracts that ensure efficient and effective coal-mine reforestation.

Possible Contracting Terms

There is no perfect way to ensure through legal contracts that postmining land will support productive forests. There are, however, contract terms that can be applied to encourage that result. Below, we describe such terms and discuss the advantages and disadvantages of each.

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1. Specify the number of live tree seedlings of certain species or species groups that will grow on the site after mining.

Mine reclamation regulations generally require that a certain number of live seedlings be present at bond release on land reclaimed to forested postmining uses. For example, Virginia requires at least 400 live seedlings (at least 1 foot tall) per acre of species that "have utility for the approved postmining land use."

Advantages:

- **Ensures that a postmining forest is both present and comprised of species desired by the landowner:** Use of this term would ensure that the site is restored to a forest postmining use with tree species desired by the landowner.

- **Easy to verify:** Living trees on the mine site can be counted easily. A forester can determine whether or not the number of live trees complies with contract requirements using statistical sampling procedures without counting each tree. If the mining permit requires the same species as the contract, and the contract specifies bond release as the compliance date, then the count of living trees required of the mining firm for bond release can also determine if this contract term has been met.

Disadvantage:

- **Does not ensure favorable soil properties:** A major disadvantage to sole reliance on this term is that it does not ensure mine soil properties that are favorable to growing trees. Seedlings can survive on a wide range of soils, but survival does not mean that those trees will thrive (figure 1). Soil properties govern long-term forest productivity; owners who manage postmining forests as financial investments will want to ensure that both favorable soil properties and live trees of the desired species are in place after mining.

2. Specify the type of soil or overburden materials to be placed on the surface to a depth of at least 4 feet after mining.

The soil and overburden materials placed by the mining firm on the land surface during reclamation will have a direct effect on the postmining forest's productivity.

Generally speaking, slightly acid sandstone mixed with materials from finer-textured rocks such as shale and siltstone (not to exceed a one-to-one ratio of sandstone-to-siltstone/shale) forms excellent soils for trees. Sandstone from the upper portion of the overburden column, directly below the premining soils, is generally favorable for forest production. These materials can be identified visually by brownish colors caused by natural weathering and are commonly called "brown weathered sandstone." Placing topsoils excavated from elsewhere on the mining site onto the surface during reclamation or mixing natural soils with rock materials can improve the mine site's suitability for forest trees and encourage growth of forest understory species. If brown weathered sandstone and/or soil materials cannot be placed on the surface economically, grey sandstone that is

Figure 1. Minesoil properties can have a dramatic effect on tree growth. The eastern white pines in both photos were the same age (8 years) when the photos were taken. The pines in the left-hand photo grew on a soil formed from compacted alkaline shale, while those in the right-hand photo grew on minesoil formed from loose, moderately acid sandstone.

slightly acidic and breaks down into soil-like fragments can also make good mine soil for trees. Materials to avoid include high-pH sandstone, siltstone, and shale – although these materials can be mixed with more favorable materials, up to a one-to-one ratio.

Suitable materials must be placed on the surface to a depth of at least 4 feet to assure that they provide an adequate depth for rooting by the full-grown trees.

A contract might state that some percentage of the land surface (for example, 90 percent) will be comprised – to a depth of 4 feet or more – of soils constructed from excavated soil, a single rock type, and/or a mixture of several rock types, each of which has favorable properties for growing trees.

Advantages:

- **Familiar to mining personnel:** Mining operators routinely identify "durable rock" strata for the purpose of constructing rock drains and "toxic strata" for special handling. Thus, mining personnel are familiar with procedures to identify individual rock strata and place them in specific locations.

- **Direct effect on forest productivity:** The properties of materials used to construct the postmining soil will have a direct influence on survival and growth of planted trees.

- **Easy to verify:** Excavated soils can be easily identified visually, while individual rock types are usually consistent in appearance. Thus, the presence of specified materials on the surface often can be verified by visual inspection. If several rock strata have similar appearances but different chemical properties, simple chemical tests that can be performed on site, such as pH, could also be used. Either visual inspection during mining and reclamation or the use of a backhoe to dig 4-foot pits at random locations after reclamation, would verify that materials had been applied to sufficient depth.

Disadvantages:

- **Does not specify compaction avoidance:** Compaction of surface materials by heavy equipment will degrade the site's forest capability and should be avoided.

- **May affect operator flexibility:** The process of creating a productive soil will be less costly if the operator has flexibility in selecting materials for surface placement. Therefore, specifying several rock and soil types as allowable for surface placement will generally be more cost-effective than specifying a single material.

3. Specify that practices which compact the mine soil shall be avoided.

Scientific research demonstrates clearly that soil compaction hinders the survival and growth of trees (Torbert and Burger 1994; ARRI Forest Reclamation Advisory No. 3). Areas being prepared for trees should be graded loosely, using a small dozer when possible and minimizing the number of dozer passes. A loose mine soil with a rough surface is best for trees. Practices intended to create smooth surfaces (such as "back blading") and to cover the surface with dozer cleat marks ("tracking in") will hinder postmining tree growth. Land that has been compacted by equipment, such as parking and maintenance areas, can be loosened by deep ripping (ARRI Forest Reclamation Advisory No. 4).

Although some mining agencies have discouraged "loose grading" practices in the past, this is no longer the case (ARRI Forest Reclamation Advisory No. 1). Most mine inspectors will approve low-compaction grading without problem or difficulty because this practice is allowed under the Surface Mining Control and Reclamation Act (SMCRA), and because state and federal mining agencies participate in the Appalachian Regional Reforestation Initiative (ARRI), which encourages the Forestry Reclamation Approach (FRA; ARRI Forest Reclamation Advisory No. 1).

Advantages:

- **Easy to verify:** Marks left by equipment operation are usually visible to the naked eye.

  Another method of verification is to walk the mine site with a spade or shovel after reclamation. Surface compaction can be checked by putting a modest amount of foot pressure (50 pounds) on the shovel while rocking the shovel tip to bypass coarse fragments. If a rock big enough to block the shovel is encountered, move to another spot. The depth of shovel penetration will be affected by the degree of compaction and is an indicator of forest-site quality. If the shovel is easily able to penetrate the top 9 to 12 inches or more, the surface materials should be loose enough to support healthy trees (see table 1).

If the landowner is unfamiliar with the mining firm's methods of operation, verification may also include random excavations to assure that compacted soils have not been covered with a thin, rough-graded, or scarified surface.

- **Reduced costs for the mining operator:** Leaving a rough, loosely graded surface can save the operator hundreds of dollars per acre relative to the cost of preparing the smoothly graded surfaces that are often necessary for nonforested postmining land uses.

Disadvantage:

- **Does not specify overburden type:** On most mines, the soil materials vary widely in properties that influence survival and growth of planted trees.

4. Specify mine soil properties.

The term "mine soil" refers to the materials left on the reclaimed land surface to support growing plants. Mine soil properties will have a direct effect on the postmining forest's productivity.

Scientific research shows that the following mine soil properties influence the survival and growth of planted trees (table 2). Contracts using this term should state that desirable soil properties must extend to at least a 4-foot depth.

1. Soil pH and soluble salts: Soil pH influences soil nutrients' availability to plants, while high levels of salts in the soil reduce the trees' ability to grow roots. Both can be measured on-site with portable field equipment. The ideal soil pH is 5.5 to 6.5, while a range of 5.0 to 7.0 will be adequate for most Appalachian hardwood species. Soluble salts should be below 1,000 parts per million (ppm).

2. "Coarse fragments" are mineral particles larger than about 1/12 inch (larger than 2 millimeter) in diameter, and "soil-size" particles are those that are smaller than 2 mm. Mine soil with large amounts of coarse fragments cannot provide growing trees with water and nutrients as effectively as soils with more soil-size particles. The mine soil should contain at least 35 percent soil-size particles.

3. The term "soil texture" refers to the relative distribution of sizes among the soil-size particles. Larger soil-size particles (sands) are unable to retain and supply water and nutrients to the trees as well as the smaller particles (silts and clays), but some sands are needed so the water and air can enter and move through the soil. The right mixture of sand, silt, and clay is needed for trees. Thus, loamy textures are favored over pure sands or clays.

4. The term "bulk density" refers to the density of soil materials. A low bulk density indicates a loose soil that will allow rainfall to infiltrate easily, thus helping to prevent erosion, and will not impede root growth. Bulk density measurements apply only to the soil-size particles. In general, the soil bulk density should be less than 1.4 grams per cubed centimeter.

Table 1. The relationship among soil-density condition, shovel-penetration depth, forest-site quality, and return on a forestry investment (based on Probert 1999; Burger et al. 2002; Burger et al. 2009 [VCE publication 460-138]).

Soil-density condition	Very dense	Dense	Moderately compacted	Slightly compacted	Loose
Shovel penetration (inches)	0-1	1-3	3-6	6-9	9-12
Site quality	poor	fair	medium	good	excellent
Oak site index*	40	50	60	70	80
Typical use for wood products	none, firewood, chips	pulpwood, chips	railroad ties, mine props, pallets	saw timber	high-quality saw timber, veneer
Relative return on investment	negative	negative to zero	1x	2x	4x

*Approximate height in feet of a white or red oak growing in this soil at age 50. These ratings assume that all other factors (other minesoil properties, ground cover, seedling quality, etc.) affecting productivity are optimum.

5. Soil-nutrient content and availability: Phosphorous affects the growth of planted trees over the long term; the adequacy of soil phosphorus is determined by the amount of phosphorous fertilizer applied during reclamation and the ability of soil materials to retain that phosphorus in plant-available forms.

If the mine soil has been constructed from unweathered rocks, some soil properties will change as the postmining surface materials are exposed to oxygen, water, and growing plants. Soil pH, for example, may change within a few months after soil placement if sulfide or carbonate minerals are present. Soluble salts in unweathered overburden rocks will decline as the mine soil weathers, although this process occurs more slowly. Coarse-fragment contents often decline as rock fragments weather and break into smaller particles, and aeration porosity can increase as plant roots and soil animals loosen the soils. Because soil properties change with time, contract terms can require verification some time after surface materials have been placed, six months to one year at minimum.

Bulk density, however, does not change rapidly and cannot be altered through the application of fertilizers or other soil amendments, although compacted mine soils can be loosened with deep ripping (ARRI Forest Reclamation Advisory No. 4). It is critical that the mine soil be left in a low-density, uncompacted condition (ARRI Forest Reclamation Advisory No. 3).

Advantages:

- **Soil properties govern long-term forest productivity:** A contract that specifies postmining soil properties can ensure that the reclaimed mine land is able to support the landowner's goals. Bulk density is the soil property that is generally most critical to reforestation success.

Table 2. Soil properties and reclamation practices[a] that can produce sites suitable for reforestation with native Appalachian hardwoods with a site index[b] of 75 feet or more.

pH	5.5 - 6.5	Can generally be achieved by avoiding high-pH siltstones and shales, and by avoiding acid-forming materials, in surface soils.
Soluble salts[c]	< 1000 ppm	Can generally be achieved by using weathered sandstone or a mixture of unweathered sandstone and siltstones to construct the surface soils, and assuring that no acid-forming materials are present.
Bulk density	≤ 1.4 g/cm^3	Can be estimated using a common hand spade or pointed shovel by pressing it into the soil with a modest amount of foot pressure (50 pounds) and rocking the shovel tip to bypass rocks and other coarse fragments. This method should enable the shovel to penetrate at least 9 inches. Bulk density can also be measured by technical personnel using soil- measurement procedures.
Coarse fragment content	< 65% of soil mass	"Coarse fragments" are rock fragments larger than sand (>2mm).
Soil depth to compacted layer or rock	> 4 feet	Minimum depth is 4 feet is a minimum depth.
Soil texture	Loam, sandy loam, or silt loam	Can generally be achieved using weathered sandstone or a mixture of unweathered sandstone and siltstone to construct the surface soils.
Phosphorus (P) fertilizer	>130 lb (as P_2O_5) applied per acre	This rate can be achieved by applying 300 lbs/acre diammonium phosphate fertilizer (18-46-0) or triple super phosphate (0-46-0), or by adding some super phosphate with other fertilizer blends.

[a] Based on research by Torbert et al. 1988; Andrews et al. 1998; Burger et al. 2002; Rodrigue and Burger 2004; Jones, Galbraith, and Burger 2005.

[b] Fifty-year site index for red oak. If soil properties are at levels shown in the second column above, tree growth should achieve the target site index.

[c] In a 1:2 soil-to-water ratio, as measured by Virginia Tech Soil Testing Laboratory.

- **Soil properties are under the mining firm's control:** Soil properties can be controlled by selecting specific overburden or topsoil materials for use in the construction of mine soils and by avoiding compaction.

Disadvantage:

- **Difficult to verify:** Use of this contracting term will require engagement by personnel who are knowledgeable in soil properties. A person with a college degree in soil science or forestry and several years experience in mine reclamation or environmental consulting should be capable of supervising these contract terms. Verification requires that the soils be sampled by qualified personnel and analyzed by a qualified laboratory – although some properties (including pH, soluble salts, and density using the "shovel" method) could be analyzed in the field.

5. Specify that a small number of eastern white pines be planted as an "indicator species" and attain a minimum growth rate.

Eastern white pine responds to soil properties in a way that is similar to hardwoods. Thus, eastern white pine growth can serve as an indicator of soil suitability for slower-growing commercial hardwoods. Eastern white pine exhibits a systematic growth pattern: each year's growth is marked by a whorl of side branches emerging from the main stem. Thus, an eastern white pine with three whorls is in its fourth year of growth. The distance between whorls (the internode length) is a measure of the growth during that year. A contract using this term could require that a certain number of eastern white pines be planted over the site (for example: 10 to 20 seedlings per acre) as a component of a species mix that supports landowner goals and that those pines' average growth rates exceed a minimum standard (see table 3).

Advantages:

- **Easy to verify:** Measuring the internode length is an easy task. Average growth could be estimated by measuring the internode distances on five to 10 randomly selected trees per acre on small sites and fewer trees per acre on larger sites.

- **Familiar to mine operators:** Eastern white pine is widely available and familiar to most planting contractors.

- **Eastern white pine is commonly found in native hardwood forests:** Even though the landowner's primary objective may be commercially valuable hardwoods, the small number of eastern white pines per acre will enhance the forest habitat for game species.

Disadvantages:

- **Factors over which the operator has no control will influence eastern white pine growth:** For example, weather and climate in a given year can be either favorable or unfavorable. Over a 5-year cycle, however, it is likely that both good years and bad years for eastern white pine growth would occur.

- **The first few years' growth will not be indicative of long-term soil fertility or soil depth:** A good forest soil will have favorable physical and chemical properties to a depth of at least 4 feet. During the first five years of growth, eastern white pine will exploit only the top foot or two.

Summary

Coal-leasing contracts typically are negotiated by mining firms and resource owners. We have presented possible contracting terms as options; a combination of terms or all terms could be specified to help ensure

Table 3. Average length of white pine internodes equivalent to northern red oak site index. For example, for trees between the ages of 5 and 10 years, if the average length of the last three to five white pine internodes is equal to or greater than 26 inches and the mine soilminesoil is at least 4 feet deep, the red oak site index is equal to or greater than 85 feet (estimates based on data by Beck 1971;, Wenger 1984).

Site Quality	Excellent	Good	Fair	Poor
Average distance between whorls[a]	> 26 in/yr	22 - 26 in/yr	18 - 22 in/yr	< 18 in/yr
Target red oak site index[b]	85	75	65	55 or lower

[a] Average distance of three to five annual internodes for trees between the ages of 5 and 10 years.

[b] Fifty50-year site index for red oak in feet. The target site index can be determined for the soil type existing prior to mining. (Average red oak site index for a given soil series can be found in table 11 of most NRCS county soil surveys.)

the quality and value of mined land for native forests (see table 4). Of these, the one that would go the furthest toward ensuring a mine site that is favorable to the postmining forest is to specify soil properties. Contract language may combine several other terms. For example, the following contract language combines several of the possible contract terms discussed above:

> "Surface soils shall be comprised of brown weathered sandstones obtained from within 30 feet of the land surface, excavated soils, and/or gray sandstones from the _____ formation, individually or as a mixture. These materials shall extend from the surface to a depth of at least 4 feet over at least 90 percent of the mining site. After suitable materials have been placed on the surface, grading shall be conducted at the minimum level necessary to satisfy regulatory authorities so that soils remain loose and uncompacted. At least 130 pounds of phosphorous (as P_2O_5) shall be applied per acre as fertilizer. At bond release, the site shall contain at least _____ live seedlings per acre, comprised of the following species [list desired species as percentages or as number per acre] and including 10 to 20 eastern white pines per acre. The surviving eastern white pines shall attain growth rates of at least ___ inches per year, averaged over three, four, or five years as per the operator's preference."

Resource owners who desire productive postmining forests may negotiate contracts with mining firms that use a Forestry Reclamation Approach to ensure that the postmining land is able to support their ownership goals.

Mining firms can pursue coal-leasing contracts with mineral owners who retain a surface interest by developing a capability to efficiently and effectively reclaim mined sites for forestry, and by offering contract terms that ensure such practices will occur.

Table 4. Summary of contract terms reviewed.

Term	Advantages	Disadvantages
1. Specify the number of live seedlings of certain species or species groups.	Assures that desired species are present, easy to verify.	Does not ensure favorable soil properties.
2. Specify the type of soil or overburden materials to be placed on the surface.	Surface material properties affect forest productivity; easy to verify.	Does not prevent soil compaction when implemented alone; may restrict operator's materials- handling flexibility.
3. Specify the practices that compact the mine soil which shall be avoided.	Easy to verify; cost effective.	
4. Specify properties of the soil and rock materials left on the land surface after mining.	Soil properties affect forest productivity; , and the mining firm can control some soil properties.	Difficult to verify.
5. Specify that eastern white pines be planted as an "indicator species" and attain a minimum growth rate..	Easy to verify; eastern white pine growth rate is a good indicator of soil properties.	Weather, as well as soil properties, affect rate of growth. The first few years' growth will not be an indicator of soil properties at depth.

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Forest Reclamation Advisory No. 3: *Compaction Grading to Enhance Reforestation Success on Coal Surface Mines.*

Forest Reclamation Advisory No. 4: *Loosening Compacted Soils on Mined Sites.*

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